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AUTHOR	Garman, Mark B.; Northall, Jane E.
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ABSTRACT

This paper addresses one element of the educational planning process -- the objectives to be attained as a result of the implementation. The authors first discuss objectives in the context of planning in general and the relationship of planning to the process of education. Within this context, the need for goal analysis is identified. Next, there follows a discussion of organization goals; goal discovery, structures, and analysis; and regret functions. The presentation concludes with a discussion of a dynamic goal programing model and some goal programing solution procedures. The information provided is intended for a variety of audiences including both experienced and inexpreienced educational administrator-planners, one-time users, and educational planners in general. Each section of the paper is identified as being appropriate to one particular audience type. The material is also categorized and identified according to school facility planning, educational planning, urban-educational planning, and comprehensive planning. (Author/DN)

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GOAL ANALYSIS PROCEDURES

Mark B. Garman
and
Jane E. Northall

EA 005 356

Santa Clara County Component
45 Santa Teresa
San Jose, California 95110

PROJECT SIMU-SCHOOL

ED 079858

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GOAL ANALYSIS PROCEDURES

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FOREWORD

Project Simu School was initiated to consider ways of improving and simplifying the process of educational facilities planning for the educational planner. The initial intent was to develop a highly sophisticated simulation capability through a national coordinating center for educational planning, but work early in the project suggested that a single large scale simulation procedure was not feasible and that facilities planning could not thus be separated from overall educational planning. The Simu School Project accordingly decided to try to develop planning procedures and techniques to aid the local educational planner and/or consultant.

The approach of the present project is to consider educational planning as an integrated process in which the facility becomes an integral part of the evolving education program and the teaching-learning situation. The products or output of the project therefore must be aimed at the total process of educational planning and the procedures and methodologies which comprise it. The final products will be applied by the local educational planning body, the educational system, or members of the community to develop a program of educational services.

Educational planning under these constraints is an interactive process between the components of the local community. The potential user of planning products ranges from the untrained to the highly trained, and the planning products from very specific tools for specific needs to general planning methodologies and strategies. Project Simu School, therefore, is responding to the broadest possible spectrum of the needs of various levels of educational planning as well as to the actual range of individuals who may be involved in the process.

One specific element of the planning process is addressed in this paper, namely the objectives which are to be attained as a result of the implementation of a plan. The first section of this paper discusses objectives in the context of planning-in-general and the relationship of planning to the process of education. Within this context the need for goal analysis is identified.

It should be noted by the reader that the information in this paper is intended for several audiences, including (1) one-time users, who may or may not be trained in planning (parents, students, other citizens); (2) educational administrators familiar with educational planning but not specifically trained in the use of planning techniques as they are here described; and (3) experienced educational planners. For the reader's convenience, each section heading is followed by (1), (2), (3) to suggest the anticipated audience for that section.

The material also contains examples of four levels of educational planning (see Leu, Ref. 1), namely: School Facility Planning (I), Educational Planning (II), Urban-Educational Planning (III), and Comprehensive (IV). Where practical, the examples are marked with the corresponding Roman numerals to orient the reader to the level being cited.

It is anticipated that the concepts presented herein, and the analytical techniques illustrated will contribute to the improvement of comprehensive educational planning.

Lester W. Hunt, Director
Project Simu School: Santa Clara County Component

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Section 1

THE PLANNING PROCESS, GOALS AND EDUCATION (1,2,3)

The objective of this paper is to present the need for the analysis of the goals that are formulated during the educational planning process, and to describe techniques that can be applied to that task. If "education" means only the activities which occur in the formal setting--the school, then educational planning means largely facilities planning and capital investment planning. In such a case, the methods used are, for the most part, projective in nature, based on trends of student enrollment, population growth, cost curves, and similar data. But education is being defined more broadly to include all experience and not just the formal learning experiences. Education, in this sense, is the ongoing process by which the individual learns to adapt to his environment and through which society, as part of that environment, undertakes his socialization.

Given the expanded definition of education, the accelerated changes in social factors, the increasing complexity of educational programs, and added community involvement in educational planning, we need a strategy for planning which is adaptable and dynamic. The strategy must work within the constraints of today's methods, information base, and knowledge.

Planning is considered to be a continuous, dynamic process involving these activities:

1. Collecting data
2. Collating and analyzing the collected data
3. Establishing values, criteria, and decision models
4. Developing possible alternative courses of action
5. Selecting courses of action (strategy)
6. Projecting a series of activities to reach alternative objectives
7. Projecting a time series or schedule for the activities
8. Establishing review criteria and procedures
9. Reviewing the plan established
10. Making changes and repeating the sequence until the plan meets the established criteria.

The basis from which the planning sequence originates is information, which must be transcribed as accurately and thoroughly as possible in order to build a good foundation for planning. However, the data base can never be complete, due to inevitable losses in data collection (including perceptive loss), in representation and planning, and in omissions or distortions due to bias. The limitations of the information must therefore be recognized and taken into account in the planning process.

Another factor to be considered by the planner is the effect of the planning horizon--the time over which the planning process will occur. If it is too long, the environment may have changed significantly; if too short, the plan does a poor job of building toward the future.

The following factors comprise and/or influence the process of planning:

1. Planning is made from a data base that is a reflection of an operating system, but the data base is not the system;

2. Data collected are projected forward in time, but under uncertainty;

3. Alternatives are developed from which decisions for future operations are made;

4. Value systems and social utility are inherent parameters of the planning process, but are difficult to define explicitly;

5. Planning is a time-dependent multivariate process;

6. A variability can exist between planning for society, for its constraint elements, and for the individual;

7. The planning process must acknowledge and try to compensate for biases which are introduced.

Since Project Simu School is designed to include all types of planning from the very specific component to the comprehensive plan, an adequate strategy must form a framework for a wide range of possible activities and plans. Whatever the level, planning begins with data collection, which means that the situation to be considered must be transcribed into a documented form. The elements that must be documented are (1) the present situation, (2) evaluation of the present situation, (3) required actions, and (4) expected outcomes.

This paper is concerned with the last element, expected outcomes--or perhaps we should say, desired outcomes. Planning occurs only because we perceive some differences between the current state of affairs and some future "ideal" state of affairs which we can only imagine. We shall call these idealizations, or desired outcomes, "goals."* (We shall here be concerned with goals held by people; we leave the question of goals and goal-oriented behavior in other types of entities to the biologists and philosophers.)

In the process of planning for the future, two of the most important activities are analyzing and synthesizing goals. These tasks are performed in the context of systems analysis, which has come into widespread use in planning methodology in recent years. This approach suggests that an operating system, its environment, and their relationships and properties be defined before the planning process is instituted. The defined system is then analyzed and some problem identified which will be addressed by the activity being planned. We suggest here that the proposed outcomes of the activities, i.e., the goals, should be analyzed prior to adoption and implementation of a plan.

The merits of various planning activities and outputs can be judged only in relation to the plans' effectiveness (and efficiency) in "achieving" goals.

*We recognize that the terms used here may not match current local usage where, for example, "objectives" are considered attainable and "goals," by definition, are not. In this paper, we do not distinguish between "goals," "objectives," "purposes," and similar notions; all are treated as more or less synonymous.

Without solid conceptualization of the appropriate goals for a specific context, it is impossible to judge any form of planning therein. Moreover, we must be certain as to what constitutes the "achievement" of certain goals, and indeed what the term "achievement" means.

In Section 2, methods for judging effectiveness and efficiency are considered; the role of the educational planner in goal discovery and goal analysis is discussed; and various tools for goal analysis are presented.

To set the stage a little more, "goal analysis" means here the application of techniques for questioning, refining, and improving overt goal statements. Goal statements should be operational; i.e., they should provide the means by which attainment is determined. Most operational goal statements specify two components: a performance measure, and a target value for the measure. In this paper, the concept of a "regret" function is introduced as a further means for analysis of goal achievement. The regret function associated with a goal statement yields additional information by representing the notion of goal achievement vs. nonachievement. When we take this approach, goal statements are formulated or refined in such a way as to define qualitatively their associated regret functions.

We will also be considering the relationships among different goals in a given context. The most common relationship is between subgoal and supergoal, and these relationships create a hierarchy among the set of goals associated with an organization. This hierarchy may be represented by a tree network which can be analyzed to determine the sufficiency and operationality of the goals. Possible analyses of the goal tree may range in sophistication from a logical review of the goals in this format to the application of goal programming, an outgrowth of linear programming. These possibilities will be discussed and demonstrated in Section 3.

Section 2

GOAL ANALYSIS FOR EDUCATIONAL PLANNING

Organizational Goals (1, 2, 3)

It may be plausibly argued that organizational goals cannot exist. In a broad sense, admitting their existence amounts to saying the organization has "a mind of its own." To be sure, there is no such thing as an "organizational mind"; an organization does not have goals in the sense that an individual has goals. But we can, following Simon (Ref. 2) and Cyert and March (Ref. 3), talk about organizational goals in a limited sense. An application of their reasoning to the specific context of educational planning might run as follows.

We begin with a large collection of people whom we may roughly classify into several coalitions, a term we define herein to mean individuals whose individual goals are, for practical purposes, nearly identical.* Such coalitions, in the context of educational planning, would include parents, teachers, students, administrators, school boards, state and local government officials, legislators, and other interested parties. Accordingly, the actual goals of the whole group are not necessarily established by fiat, legislation, or other external mechanisms, but rather by the internal processes of bargaining and negotiations between the various coalitions. Inducements in the form of salaries, grants, policy concessions, power allocations, and other side-payments are distributed to individuals (or coalitions) in return for the contributions these individuals (coalitions) make to the organization. Organizational theory tells us that the individual's decision to participate in the organization is not predicated upon abstract concepts of altruism, but the degree to which the proffered inducements outweight the demanded contributions. Stable organizations are those that provide net "psychic profits" for their members.

The process of bargaining also establishes a set of activities and an allocation of these activities ("roles") amongst members. By definition, such individual activities must serve the actual, or implicit, goal structures which evolve from the bargaining process, insofar as the physical constraints governing the activities permit. Since in reality these actual goals are not properties of the organization as a whole but are fragmented amongst its members, we will term them collectively as the incentive structure of an organization. We shall reserve the term "goal structure" to mean only externally defined sets of goals, i.e., those goal statements made explicit relative to some organization.

In these terms, the central problem of directing organizational change (and thus of planning for educational change) is that of making incremental steps which bring an organization's incentive structure more closely in line with some explicitly defined goal structure. This statement masks a number of difficulties.

In the first place, the incentive structure of an organization is not in itself visible; only its activities are directly observable. Hence the organizational planner must try to match the incentive structure to some goal structure when the former is accessible only via the surrogate of activities.

*This definition differs somewhat from usage by the above-mentioned authors and corresponding standard game-theoretic concepts.

This point will be referred to in our discussion of goal discovery.

In the second place, explicitly defined goal structures may be incomplete, or may not exist at all. One of the central tasks of the educational planner is to create and refine such structures. Specific methods of goal refinement were suggested earlier; however, goal creation and refinement must now take place within the organization's political context, where policy concessions may be exchanged for participant inducements.

The goals of an organization are formed by the individuals of the organization based on the inherent incentive structure and the explicit goal structure. The educational planner must often assist in the refining or modification of the explicit organizational goals. The next sub section discusses the problems faced by the educational planner in undertaking these activities.

Goal Discovery (1, 2)

How can we discover what another individual's goals are or what our own goals are? There are two basic methods of discovery: interpreting overt statements regarding goals, and inferring goals from actions. All of us have come across situations (for example, in election years) where an individual's overt goal statements may differ considerably from the goals we infer from his actions. Indeed, we often think of the former as being for appearance's sale only, the latter as "real" goals. We shall assume, for practical purposes, that we are dealing with decision-makers for whom there is no basic conflict between the two; that is, with individuals who have no reason or intent to deceive themselves or others as to the nature of their goals. Therefore we shall concentrate on the analysis of the more accessible overt goal statements.

Goal Analysis (1, 2)

Goal analysis, by definition, will then refer to the application of various techniques for questioning, refining, and improving overt goal statements. This suggests that there should be criteria for judging overt goal statements. One of the most important criteria is that of operationality. That is, a goal statement should provide the means by which we may determine whether or not it has been attained, and do so in an unambiguous manner.

> Example 1 (1, 11). Consider the goal statement GS1: "All elementary schools in our school district should have enrollments sufficiently large to economically justify their continued existence."
>
>> GS1 is reasonable, since it promotes the efficient use of taxpayers' monies for education within the school district, but it is not nearly precise enough. Two equally intelligent individuals could disagree as to whether or not a given district had "achieved" this goal. In other words, GS1 is not operational, but is ambiguous.

We could refine GS1 towards operationality in several fashions. For example, we could create two or more operational subgoals serving GS1 which dealt with the measurement of revenue per student, total costs of school operation, and so forth, in such a manner that the joint achievement of all such subgoals provides for, by definition, the achievement of GS1. The use and analysis of subgoals is given in a later section. For the moment, we shall improve the operationality of GS1 via replacing it entirely by, for example,

GS2: "All elementary schools in this school district should have enrollments of at least 350 students."

GS 2 is reasonably operational, inasmuch as two or more intelligent observers could likely reach agreement as to how many students are actually enrolled in each school, and hence whether or not the goal had been achieved. (However, GS2 suffers from another deficiency: it does not provide any rationale for its performance figure, 350. Ideally, well-composed goal statements should provide a preamble of sorts as a raison d'etre for the goal in question. For example, GS2 might be prefaced with the words, "Whereas each elementary school should economically justify its continued existence, and whereas school operation costs average $350,000 per annum and revenue per student per annum averages $1,000, . . ." In other words goal statements should provide indications of which "supergoals" and "subgoals" they serve; more will be said about the supergoal/subgoal relationship later.)

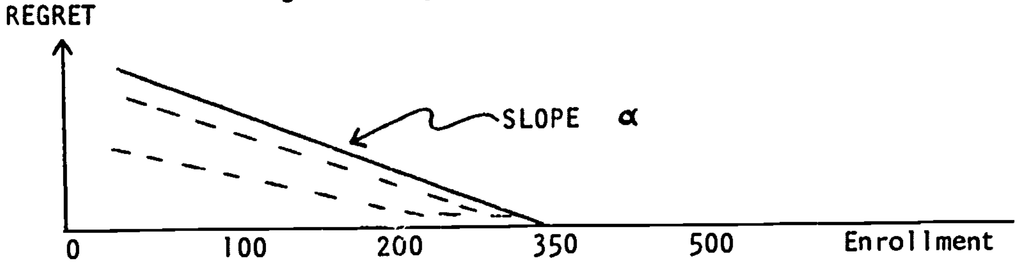
In addition to being defined in operational terms, well-formulated goal statements should yield information on what happens when the goal in question is not achieved. Since a large number of the goals we set for ourselves are never achieved, it is important to understand the "costliness" or "regret" which will occur if the goal is not achieved. Costliness may be defined in terms of dollars and/or lowered quality of educational services. Moreover, it is important to refine the concept of achievement itself. We do this in the following section.

Regret Functions (2, 3)

Most operational goal statements specify two vital components: a performance measure and a target value for the measure. A performance measure is simply a number associated with an activity, but one which has some meaning to a decision-maker. "Profit" might be used by investors when judging investment in a corporation, or "occupancy" in the case of evaluating an apartment house. In any event, a measurement process is required for any performance measure. We assume in the discussion following that the reader has some familiarity with performance measures and measurement in the context of education. In the current example, "enrollment" is the performance measure in both GS1 and GS2. The latter also provides the target value 350. When the performance measurement, enrollment, is equal to the target value 350 in some school then, by definition, GS2 has been "achieved" for that school. But what about the case when the enrollment figure is 349? Or 353, 340, 365? The goal statement itself does not expressly supply this information. Instead, we introduce the supplemental concept of a regret function as a vehicle for the analysis of goal achievement. Achievement, for the referenced goal, is defined by an enrollment figure of 350. The goal is not achieved if any other enrollment figure (higher or lower) is reached.

A regret function will be defined as a relationship between the stated performance measure and the total (psychic or real) costs associated with each value; these costs are considered only relative to the achievement or nonachievement of the goal in question. A regret function can be graphed by putting a performance measurement on one axis of a co-ordinate system and a "regret amount" associated with various values of the performance measure on the other axis. The regret will be assumed zero at the target value. For example, the regret function of GS2 might look like that in Fig. 1.

Fig. 1. Regret Function for GS2



The regret function is meant to convey the total "cost" of incurring a specified performance measurement value. In Fig. 1, all enrollment numbers at 350 and above incur zero regret under the goal. (Obviously, there are other "costs" associated with increased enrollment. However, we are considering regret as only the costs of nonachievement vis-a-vis the goal.) Decreasing enrollment under 350 results in increasing regret at a rate determined by the steepness of the slope α given in Fig. 1 (changing α might yield one of the dotted line segments.)

A regret function associated with a goal statement gives us additional information by representing the notion of goal achievement as a matter of degree, not simply achievement vs nonachievement. According to Fig. 1, then, we should be equally happy (vis-a-vis GS2) with enrollments 360 vs 385, but not equally unhappy with enrollments 330 vs 343. Figure 1 thus represents a "satisficing" approach to GS2.

Constructing and analyzing regret functions appropriate to our goal statements can be quite helpful in their refinement. Consider

<u>Example 2</u> (I, II) GS3: "Classroom utilization in the school district should be 75%." Given thusly, there are at least three interpretations for regret functions associates with GS3. The performance measure is classroom utilization, the target value is 75%. Figs. 2, 3, and 4 give some possible regret functions to associate with GS3.

Fig. 2. Barrier Type Regret Function

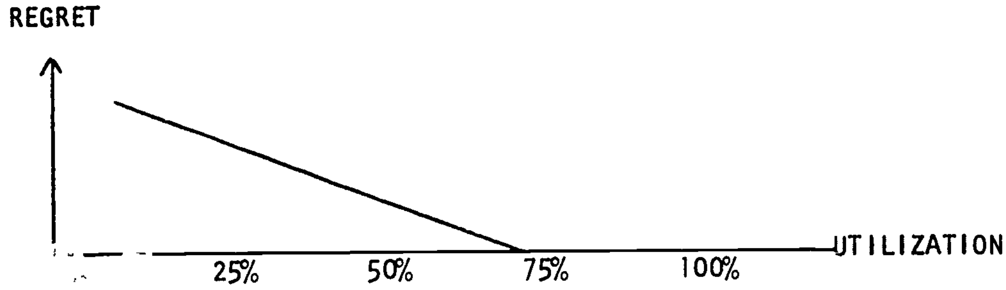


Fig. 3. Monotonic Type Regret Function

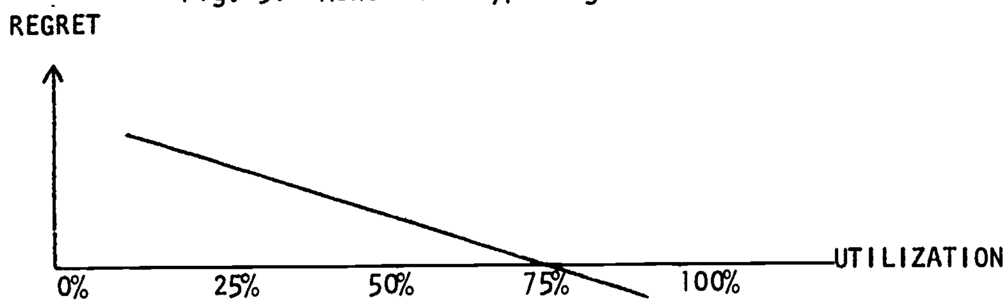
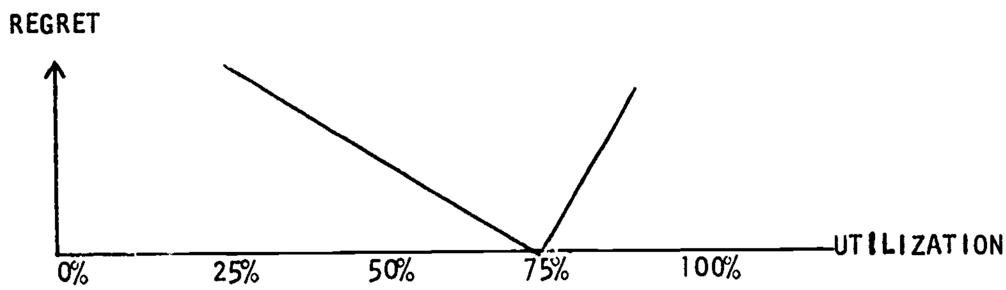


Fig. 4. V-Shaped Type Regret Function



We will qualitatively characterize these types of regret functions as (1) barrier type (Fig. 2), (2) monotonic type (Fig. 3), and (3) V-Shaped type (Fig. 4). Under the interpretation of Figure 2, additional classroom utilization above 75% is of no additional interest: we are equally satisfied. In Fig. 3, every increase in classroom utilization, even above 75%, is considered as useful. In this case, GS3 is poorly formulated--the target value should be 100% utilization. In the V-shaped regret function of Fig. 4, increases in utilization above 75% are viewed as harmful, i.e., 75% is an honest target figure. This interpretation could easily arise when, say, larger amounts of classroom utilization implied an increase of rigidity in curriculum or use of unsuitable classrooms for specialized classes.

In summary, goal statements should be formulated or refined in such a fashion as to define qualitatively their associated regret functions. When this is not done, dysfunctional results may ensue. If, for instance, facility planning decision-makers act in assuming a monotonic or barrier type regret function for GS3 when the V-shaped one was correct, they might unknowingly try to increase utilization in the first case, or ignore a critical problem associated with over-utilization in the second case.

In an earlier section we pursued the topic of goal conflict. Conflict between goals arises quite naturally in educational planning: we want to maximize educational quality at the same time that we wish to minimize costs; or provide for neighborhood schools and ethnic enrollment balance simultaneously; and so forth. Goal programming, which can use the concepts of regret functions directly, may be used to analyze and resolve goal conflict situations.

Goal Structures (2, 3)

In the preceding discussion we have used the term "goal structure" rather loosely, without indicating the nature of any structural relationship among goals. Moreover, two problems regarding the matching of incentive and goal structures were raised, but not resolved. What follows, then, will attempt to remedy this situation.

Clearly, goals may have relationships with other goals within a specific context. The most common of these is the subgoal-supergoal relationship, i.e., the situation where the attainment of some goal (the subgoal) enhances the attainment of another goal (its supergoal) in some fashion. Intuitively, this relationship may be thought of as the partitioning of supergoals into individual subgoals, each having a more elemental character.

The subgoal-supergoal relationship gives rise to a hierarchy among the set of external goals associated with an organization. The topological form of the hierarchy is, based on the partitioning concept, that of a tree network (i.e., a connected, directed graph with one source node, and exactly one path from the source to every other node). The nodes of the tree (represented pictorially as circles) are associated with the goals involved, while directed arcs (depicted as arrows) between the nodes represent the subgoal-supergoal relationship. By convention, we shall assume that these arcs begin at a supergoal and end at (point to) one of its subgoals. Thus Fig. 5 might depict a sample hierarchy of budgetary goals for, say, ten schools in a single school district. The goal names circled in Fig. 5 are given (an arbitrary) set of goal statements in Table 1 for purposes of illustration.

While budgetary goals are important, there are many other sources which yield goal hierarchies via educational or social welfare considerations. It then follows that another relationship besides that of subgoal-supergoal must inevitably appear, namely, that of conflict between goals. However, we shall leave this topic for the next section and attempt now to clarify the subgoal-supergoal relationship.

For any particular goal tree, let us designate the goal with no supergoal the origin goal, those with no subgoals the terminal goals, and all others the intermediate goals of the tree. Various tests then suggest themselves for the analysis of a goal tree:

(1) A sufficiency test. The joint attainment of all subgoals of any intermediate or origin goal should assure the attainment of that supergoal.

(2) An operationality test. All terminal goals (and perhaps some intermediate goals) must be stated in terms that involve operational measurements upon the activities of the organization involved. (Operationality as a refinement vehicle for individual goals was discussed in an earlier section.)

(3) Various mathematical tests. In the next section, we develop a quantitative model which requires the precise isolation and definition of all goals. In particular, it will enhance our ability to separate the notions of goals and constraints, and give precise meaning to the use of loss functions.

Applying the sufficiency test to the goal G and its subgoals (B_1, B_2, . . . B_{10}) in Fig. 5, we see that the test would be satisfied if the sum of the individual school budgets equals the overall budget. However, the converse test of necessity does not hold, either in this example or generally. That is, an overall budget does not imply any one particular set of individual school budgets; and in general there may be several alternative means to accomplish the same end.

In reviewing the proposed methods for analysis of a goal tree the need for a more sophisticated method of goal analysis can be identified. To put it simply, the need is due to the number of intermediate and terminal goals that are posed as a means of achieving an origin or supergoal. Each goal must not only be individually analyzed but also must be analyzed as it relates to all the other goals. One analytical method, goal programming, which can accomplish the necessary complex analysis is discussed in the following section.

Fig. 5. A Sample Budgetary Goal Structure

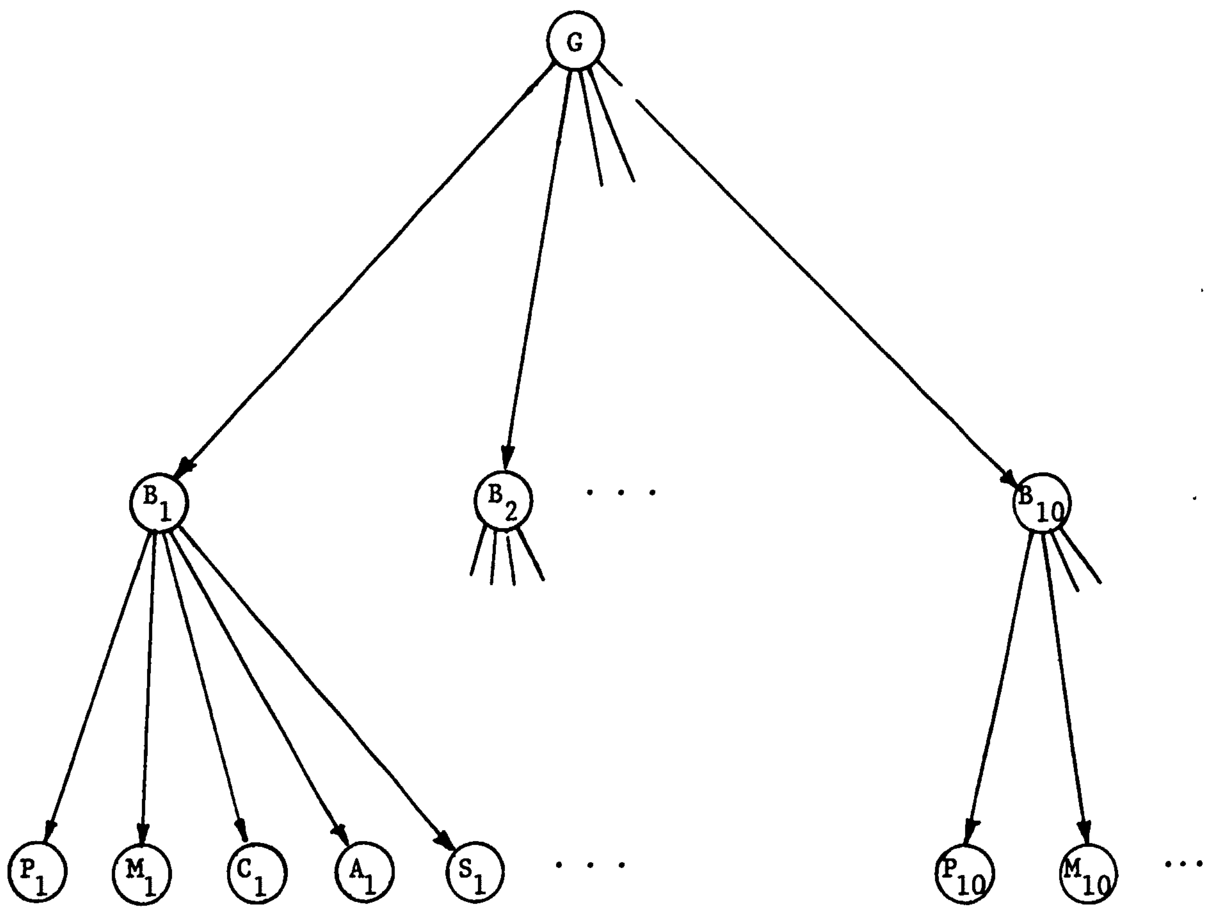


Table 1

GOAL NAMES AND DEFINITIONS FROM FIGURE 5

G: The total expenditures of all ten schools should be as close as possible to g (= \$3.7 million, for example).

B_1: The expenditures of school #1 should be as close as possible to b_1 (= \$.33 million, for example).

B_2: The expenditures of school #2 should be as close as possible to b_2 (= \$.38 million, for example).

.

.

.

B_{10}: ...

P_1: The expenditures for academic personnel at school #1 should be as close as possible to p_1 (= \$.27 million, for example).

M_1: The expenditures for facilities, maintenance at school #1 should be as close as possible to m_1 (= \$.02 million, for example).

(... and so on for capital improvements (C_i), administrative personnel (A_i), expendable supplies (S_i), etc., for school i, i = 1, 2, ···, 10.)

Section 3

GOAL PROGRAMMING (3)

Goal programming is an outgrowth of linear programming, applied to collections of goal trees. We shall give an illustration of its application to a single supergoal-subgoal combination, and then expand this illustration to bring in other portions of goal trees, in the context of educational planning. Obviously, a complete analysis of the latter context cannot be given in this short paper, but at least the methodology may be illustrated. The succeeding section will then indicate extensions to formulate a model incorporating the dynamic, i.e., time-dependent, aspects of goals and constraints.

Consider the origin budgetary goal of Fig. 5, G, and its subgoals (B_1, B_2, . . . $.B_{10}$). Assume that corresponding small letters, properly subscripted, designate the dollar amounts; that is, g represents the overall budget amount, b_i represents the budget amount for the i^{th} school and so forth. Let x_i represents the actual expenditures of the i^{th} school. Goal G then asserts that it is desirable that

$$\sum_{i=1}^{10} x_i = g, \tag{1}$$

where we have knowledge of the constraints $x_i \geq 0$, $i = 1, 2, \cdots 10$. Since Eq. (1) cannot necessarily be achieved, we add a slack variable $y^- \geq 0$ and a surplus variable $y^+ \geq 0$, which represent the amounts by which actual summed expenditures are less than, or greater than, g respectively. y^- and y^+ may be chosen such that $y^- \cdot y^+ = 0$, i.e., one or the other is zero (or both may be, in which case the goal G is actually achieved). The corresponding goal (linear) program is

$$\text{minimize:} \quad y^- + y^+ \quad (\text{"total regret"})$$

$$\text{subject to:} \quad \sum_{i=1}^{10} x_i + y^- - y^+ = g$$

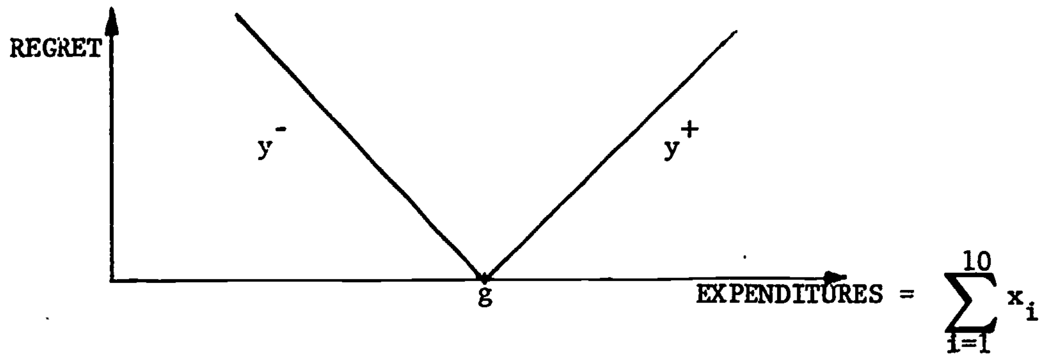
$$x_i \geq 0$$

$$y^-, y^+ \geq 0$$

$$y^- \cdot y^+ = 0$$

That is, we wish to minimize the total budgetary deviation from g subject to the operant constraints. In terms of our previous discussion on regret functions, $y^- + y^+$ represents mathematically the "cost" of total budget underage and overage, which corresponds to the V-shaped regret function of Fig. 6.

Fig. 6. Regret Function Corresponding to Formula (2)

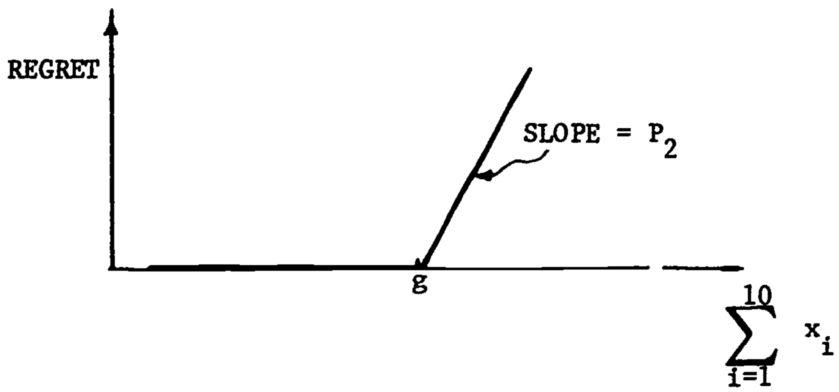


Alternatively, we may assign loss rates P_1 and P_2 to budget underage and overage, as in the following linear program:

$$
\begin{aligned}
\text{minimize:} \quad & P_1y^- + P_2y^+ \\
\text{subject to:} \quad & \sum_{i=1}^{10} x_i + y^- - y^+ = g \qquad (3) \\
& x_i \geq 0 \\
& y^-, y^+ \geq 0 \\
& y^- \cdot y^+ = 0.
\end{aligned}
$$

If P_2 P_1, then this would reflect a higher priority being placed upon avoiding a deficit than upon avoiding a surplus. In particular, $P_1 = 0$ would mean zero regret for all underage; that is, a barrier-type regret function depicted in Figure 7.

Fig. 7. Regret Function Corresponding to Formula (3)



The goal programs (GP's) Eq. (2) and (Eq. (3) are rather trivial in the sense that they can always be solved to exactly meet goal g. This result develops because the goal programs assume that the variables x_i are simply chosen by the decision-maker, hence he may choose them in such a fashion that $\sum_{i=1}^{10} x_i = g$. In other words, they have ignored the interactions with other, possibly conflicting goals which also exist within the system. Moving down the goal structure of Table 1, for example, let us incorporate the individual school budgetary goals (B_1, $\cdots B_{10}$) by letting the variables r_i, q_i, u_i, v_i, and w_i be the actual expenditure levels for academic personnel, facilities maintenance, capital improvements, administrative personnel, and expendable supplies, respectively, whose targeted (goal) amounts are p_i, m_i, c_i, a_i, and s_i. Then we add slack and surplus variables, y_i^- and y_i^+, for the ith school. GP (2) with these new additions becomes

$$\text{minimize:} \quad y^- + y^+ + \sum_{i=1}^{10} y_i^- + y_i^+$$

$$\text{subject to:} \quad \sum_{i=1}^{10} x_i + y^- - y^+ = g \tag{4}$$

$$r_i + q_i + u_i + v_i + w_i - x_i = 0$$

$$x_i + y_i^- - y_i^+ = b_i \, ,$$

$$x_i, y^-, y^+, y_i^-, y_i^+ \geq 0 \qquad i = 1, 2, \cdots 10$$

$$r_i, q_i, u_i, v_i, w_i \geq 0$$

$$y^- \cdot y^+ = y_i^- \cdot y_i^+ = 0$$

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GP (4) is no longer trivial since there may be conflict between the overall budgetary goal G and the goal $(B_1, B_2, \cdots B_{10})$. Therefore, it may be important to assign priority coefficients multiplying the $(y^- + y^+)$ and the $(y_i^- + y_i^+)$ terms appearing in the objective function GP (4), as before.

So far we have applied goal program models only to the simple budgetary goal tree of Fig. 6. Since budgets are measured quantitatively, it might be expected that goal programming readily applies. What about other performance goals, where we may deal in less tangible items than dollars? The whole point of the operationality test is to assure well-defined measures upon the activities of an educational organization which can be then compared to target figures. Let us again take GS3 as an example, and assume that 75% is the zero point of a V-shaped regret function by the rationale that was argued earlier. Let the following variables be defined:

z_i = the total number of available (physical) classroom-hours in the i^{th} school

z_i' = the number of utilized classroom hours in the i^{th} school

GS3 can be then translated to:*

$$\frac{\sum_{i=1}^{10} z_i'}{\sum_{i=1}^{10} z_i} = .75 \qquad (5)$$

Among the operant constraints would be $z_i \geq z_i'$. For the purposes of this illustrative example, we might also assume that the academic personnel expenditures, r_i, are proportional to classroom hours utilized in the i^{th} school; e.g.,

$$\alpha\, r_i = z_i', \; i = 1, 2, \cdots, 10, \qquad (6)$$

where α is some coefficient. Equation (6) then provides an interface between GS3 and the budgetary goal structure, yielding another possible source of goal conflict. That is, our separate budgetary and utilization goals may not be capable of joint attainment.

---

* Or was it the intent to apply GS3 to each school in the district individually, in which case the goals would be $z_i'/z_i = .75$ for $i = 1, 2, \cdots, 10$? The mathematics here forces us to resolve such questions, a point alluded to in an earlier section.

In Eq. (5), a slack variable, h^-, and a surplus variable, $-h^+$, are required. Thus $h^- + h^+$ is added into the objective function and $\sum_{i=1}^{10} z_i' - .75 \sum_{i=1}^{10} z_i + h^- + h^+ = 0$ should be included among the constraints. The GP problem is now

$$\text{minimize:} \quad P_0(y^- + y^+) + \sum_{i=1}^{10} P_i(y_i^- + y_i^+) + P_{11}h^- + P_{12}h^+$$

$$\text{subject to:} \quad \sum_{i=1}^{10} x_i + y^- - y^+ = g$$

$$\sum_{i=1}^{10} z_i' - .75 \sum_{i=1}^{10} z_i + h^- + h^+ = 0$$

$$r_i + q_i + u_i + v_i + w_i - x_i = 0 \tag{7}$$

$$z_i \geq z_i'$$

$$\alpha r_i - z_i = 0$$

$$x_i + y_i^- - y_i^+ = b_i$$

$$\text{all vars.} \geq 0$$

$$\text{slack, surplus var. products} = 0$$

where $P_0, P_1, \cdots P_{12}$ represents the priorities assigned to all the goals considered thus far.

Continuing in this fashion, we can proceed to include other relevant goal statements in the GP model. Further expansion here will not be undertaken as no further illustrative value would be gained. Also, further expansion would involve switching to a more compact notation than the one used to this point.

Towards A Dynamic GP Model (3)

So far no explicit use of time has been included in the GP model. Yet it is clear that budgets change, school populations grow and decline, and even the goals may change over the years. These facts may readily be modeled by duplicating all variables for each period, e.g., a financial year, and adding constraints describing the system dynamics. For instance, the static variable for the classroom hours available in the i^{th} school, z_i may be considered as $z_{2i}, z_{3i}, z_{4i}, \cdots, z_{9i}$, where the first subscript indicates the year number of the current decade, i.e., 1972, 1973, ···1979. Their simple dynamics might be expressed as the following constraints:

$$z_{j+1,i} = z_{j,i} + \beta c_{j,i} \tag{8}$$

That is, next year's total of available classroom hours is equal to this year's total plus a coefficient, β, times last year's capital improvement expenditures. Other variables may be handled in analogous fashion, for example, as in the GP (9):

$$\begin{aligned}
\text{minimize: } & \sum_{j=2}^{9} P_{jo}(y_j^- + y_j^+) + \sum_{j=2}^{9} \sum_{i=1}^{10} P_{ji}(y_{ji}^- + y_{ji}^+) \\
& + \sum_{j=2}^{9} (P_{j11}h_j^- + P_{j12}h_j^+) \\
\text{subject to: } & \sum_{i=1}^{10} x_{ji} + y_j^- - y_j^+ = g_j, \; j = 2, 3, \cdots 9 \\
& \sum_{i=1}^{10} z'_{ji} - .75 \sum_{i=1}^{10} z_{ji} + h_j^- + h_j^+ = 0 \; , \; j = 2, 3, \cdots, 9
\end{aligned} \tag{9}$$

$$r_{ji} + q_{ji} + u_{ji} + v_{ji} + w_{ji} - x_{ji} = 0, \quad \begin{array}{l} j = 2, 3, \cdots, 9 \\ i = 1, 2, \cdots, 10 \end{array}$$

$$z_{ji} \geq z'_{ji} \quad , \quad \begin{array}{l} j = 2, 3, \cdots, 9 \\ i = 1, 2, \cdots, 10 \end{array}$$

$$\alpha r_{ji} - z'_{ji} = 0 \quad , \quad \begin{array}{l} j = 2, 3, \cdots, 9 \\ i = 1, 2, \cdots, 10 \end{array}$$

$$x_{ji} + y^-_{ji} - y^+_{ji} = b_{ji} \quad , \quad \begin{array}{l} j = 2, 3, \cdots, 9 \\ i = 1, 2, \cdots, 10 \end{array}$$

$$z_{j+1,i} - z_{ji} - \beta c_{ji} \quad , \quad \begin{array}{l} j = 2, 3, \cdots, 8 \\ i = 1, 2, \cdots, 10 \end{array}$$

All vars. ≥ 0

Slack, surplus var. products = 0

The above GP includes the structural dynamics in Eq. (8); other aspects of dynamics could be easily included, e.g., budget carryovers between years, hiring decisions vs. personnel levels, facilities maintenance policies, expendable supply carryovers, etc.

Goals in addition, may be given for several time periods. For example, classroom utilization goals may change from year to year. Such dynamic goals may yield some interesting analysis. It is conceivable, for instance, that the same two goals for different points in time may be in conflict with one another, depending on the rest of the goal structure.

Goal Programming Solution Procedures (3)

Ordinary linear programming algorithms (with certain adaptations) yield solutions to GP formulations, so we shall not cover these here. Among their outputs can be included:

(a) the optimal values of all decision variables

(b) whether or not each goal is attained under the given priority scheme

(c) the values of slack or surplus variables corresponding to all unattained goals.

(An example of such outputs may be found in Refs. 4 and 5.) In addition, sensitivity studies may be performed with these algorithms. For example, a small change in some budget goal might produce another small change in an optimal but nonzero slack or surplus variable. This procedure allows a decision-maker to know how much improvement in, say, a welfare-oriented goal can be purchased with each additional dollar.

The main value of goal analysis, however, is often in the process of rigorous formulation itself rather than in obtaining actual solutions. The fact that there are readily available solution algorithms comes largely as a bonus.

Section 4

SUMMARY

The role of the educational planner includes several tasks related to goals or objectives. It is necessary therefore for the planner to be aware of the role of the organization in formulating goals and of the factors in the organization which shape the articulated goals. The planner may or may not be responsible for the initial definition of goals but it can be expected that the planning activity must include analysis and possible modification of goals. Analysis of goals prior to implementation of a plan and utilization of the results of the analysis will increase the probability of the defined objectives more closely relating to the intended objectives. This paper has presented several tools which can be utilized in goal analysis. In accord with the objectives of Simu School, analytic tools for various levels of user populations are provided. We believe that all the methods could be applied to any of the four levels of educational planning which the Simu School project has defined.

The concept of a regret function is introduced as a vehicle for the analysis of goal achievement. Most operational goal statements specify two vital components: a performance measure and a target value for the measure. Goal analysis based on the regret function permits the planner to obtain information relative to the effects of non-achievement of a goal. Based on the results of the analysis the goal statements can be reformulated, if necessary, to quantitatively define their associated regret functions.

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